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DESCRIPTION

OF A

PLANETARIUM,

OR

ASTRONOMICAL MACHINE,

WHICH EXHIBITS THE MOST REMARKABLE
PHÆNOMENA, MOTIONS, AND REVOLUTIONS,
OF THE
UNIVERSE.

Invented, and partly executed, by the celebrated
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MEMBER OF THE ACADEMY OF SCIENCES AT ERFURT,

And finiſhed and completed,
BY Mr. ALBERT DE MYLIUS,

London.

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DESCRIPTION, &c.

THIS Aſtronomical Machine is not to be claſſed among thoſe trifling mechanic conſtructions, which, though they often exhibit great ingenuity, are of no further utility than to ſurpriſe, or amuſe, the illiterate ſpectator, and are always found defective in the eyes of competent Judges.

The circumſtantial deſcription, which we here propoſe to give, of this ſuperb Machine, will convince our readers that it differs widely from the Inventions mentioned above, and that it is even far ſuperior to the many ingenious mechanical productions which have hitherto obtained general approbation, not only on account of the great exactitude of every Phænomena it repreſents, but alſo on account of the ſimplicity and ſolidity of its Mechaniſm: qualities, which undoubtedly place it among the moſt ingenious and remarkable Maſter-pieces of Mechanics, and which render it the fitteſt and moſt agreeable medium through which we may obtain a thorough knowledge of that moſt ſublime and entertaining Science—the Science of Aſtronomy. We will only add here, that the Inventor of this Machine was one of the firſt geniuſes, in mechanics, of this century, and univerſally known as ſuch, by his invention of a MACHINE of CALCULATION, of a particular Balance, and various Watches, and Clock-works.

In order to prove more fully the ſuperiority of this curious Machine over all others of the kind, it will be neceſſary to divide the deſcription thereof into three different ſections, in which we ſhall explain:

I. The different Planetary ſyſtems which this Machine exhibits,
II. Its Mechaniſm.
III. Its Figure.

SECTION I.

Of the different Planetary Syſtems.

The different Planetary ſyſtems repreſented by this Machine are:

I. The Solar ſyſtem,
II. The particular ſyſtems of the Planets which have Satellites, viz.
  1. The ſyſtem of the Earth.
  2. The ſyſtem of Jupiter.
  3. The ſyſtem of Saturn.
III. The Celeſtial ſphere, or the Solar ſyſtem as viewed from the Earth.
IV. The Chronometer.

I. THE

I. The Solar System.

The Sun is placed in the centre of an horizontal ring of two feet diameter, repreſenting the Ecliptic, and on which are delineated the 12 ſigns of the Zodiac, with their diviſions. The Planets turn round the Sun in the following order and diſtances, which are proportioned to one another, as the numbers 4, 7, 10, 15, 52, 95, viz.

	Days.	Hours.	Min.	Seconds.
Mercury in	87.	23.	14.	17½.
Venus	224.	16.	41.	25.
The Earth	365.	5.	48.	45½.
The Moon round the Earth	27.	7.	43.	5.
Mars	686.	22.	21.	0.
Jupiter	4330.	12.	47.	0.
Saturn	10747.	3.	23.	0.

The conſtruction of the wheel-work is ſo exact, that the diſtance of the Planets from their mean places in the Ecliptic, according to theſe determinations of time, does not amount to an error of a ſecond, nor even a fraction. This aſſertion may be verified by the number of teeth of each wheel, which will be found conformable to the ſtricteſt rule in Mechanics.

We have, in general, followed the ſyſtem of the celebrated MM. De la Lande, and Hell, and wherever theſe learned Aſtronomers do not perfectly agree, in the determination of the time of the motion of different planets, we have taken the mean of their aſſertions.

This repreſentation of theſe Planetary revolutions, ſo exactly calculated, is one of the greateſt advantages of our Machine, by which it diſtinguiſhes itſelf from many others, where minutial variations have been neglected: for, after the expiration of ſeveral years, the difference, or neglected reſts of ſome ſeconds, muſt be conſiderable.

None of the wheels have more than 150 teeth, which renders them light, ſolid, and of a middle ſize, and contributes greatly to give a light and eaſy motion to the Machine; and the whole is arranged in ſo curious a manner, that the Planet which moves ſwifteſt, puts in motion another of a ſlower courſe: by which arrangement it was not neceſſary to multiply the number of wheels.

The times of the planetary revolutions, as ſtated above, are to be underſtood as of their mean motion, by which the Planets deſcribe, in equal times, equal parts of their orbits. We have, however, endeavoured to reduce that mean motion to true motion; and eſpecially in the planets Mercury, Mars, Jupiter, and Saturn, which deſcribe very conſiderable Ellipſes. As to the others, viz. Venus, the Earth, and the Moon, we have thought that reduction ſuperfluous, the difference of their true and mean motion being ſcarcely perceptible, as well on account of the ſize of the ſyſtem, as alſo becauſe their orbits are almoſt circular, and their diameters very ſmall.

But, in the determination of the motion of the former Planets, we have taken particular care of this difference, which, according to M. Cassini, is 24 degrees in Mercury, $10\frac{1}{2}°$ in Mars, $5\frac{1}{2}°$ in Jupiter, $6\frac{1}{2}°$ in Saturn; ſo that it may be ſeen diſtinctly when any one of theſe Planets is in its Aphelion or Perihelion.

The obſervations of Aſtronomers plainly prove what we have here aſſerted, for the conjunctions of the Planets happen preciſely in the times calculated in the Aſtronomical Ephemeris; whereas, if the difference above mentioned had not been attended to, there would be very often a miſtake of ſeveral days.

The orbits of the Planets are circular planes, or rings, properly inclined to the orbit of the Earth, which is perfectly horizontal, under the angles determined by Aſtronomers. They interſect the Ecliptic in two points directly oppoſite, and repreſent the aſcending and deſcending Nodes of the Planets. By theſe means not only the latitude and longitude of the Planets is eaſily known, but alſo the time when they enter in their Nodes.

The Planets are repreſented by ſmall globes, faſtened to ſmall rods of ſteel, which riſe perpendicularly between the orbits, above the horizontal Mechaniſm.

The ſize of all theſe globes is in due proportion to each other, except that of the Sun. The diameter of the globe repreſenting the earth, which we accept for the unity, is $1\frac{1}{2}$ lines; the diameter of the Moon about $\frac{1}{3}$ of the former, that of Mercury rather more than one third part, and that of Venus $\frac{-}{9}$, Mars $\frac{3}{4}$, Jupiter $10\frac{1}{2}$, and Saturn $9\frac{1}{2}$. The ſize of the globe repreſenting the Sun has been proportioned to the ſpace which remained unoccupied. This globe, in its due proportion to the others, ſhould have been of the ſame ſize as the celeſtial globe which repreſents the apparent motions, &c. of the Planets, and conſequently its diameter would have been 107 lines, or 1 foot.

Saturn revolves round the Sun, being ſurrounded with its wonderful ring, which has an inclination of 30°. to the orbit of Saturn; and as, during its periodical revolution round the ſun, its axis always preſerves its paralleliſm, the Planet does not always preſent the ſame figure to the Earth, for ſometimes its anſes only appear, and ſometimes it is not viſible at all.

In this repreſentation of the Solar ſyſtem we have, for the ſake of ſimplicity, omitted the following objects:

1. The obliquity of the axis of the Sun, of Venus, and of the Earth; becauſe the obliquity of the axis of the Sun, as well as that of the Earth, is particularly repreſented in the ſyſtem of the Earth.

2. The diurnal rotation of the Planets; becauſe the globes are too ſmall for making any obſervation on them, and beſides that this rotation of the Sun and the Earth is alſo particularly repreſented in the ſyſtem of the Earth.

3. The ſatellites of Jupiter and Saturn, becauſe the ſyſtems of theſe Planets are repreſented ſeparately on the oppoſite ſide of the Machine.

4. The motions of the line of the Apſides, or the preceſſion of the Aphelion and of the Nodes; becauſe Aſtronomers do not agree in the determination of the times relative to thoſe changes, which, beſides this, are very ſlow, and almoſt imperceptible. We have, however not quite neglected this point; for the Machine is conſtructed in ſuch a manner, that it is eaſy to advance, always for the ſpace of a century, the place of the Aphelion and the Nodes, the difference not being ſenſible in a ſmaller part of time.

From this it will appear, that, by the aſſiſtance of this Machine, the different relations of the whole Solar ſyſtem may be ſeen at one view; the various poſitions of the Planets may be known for any given time, without calculation; and all the revolutions of the Heavens, ſuch as we perceive them from the Earth, may be eaſily explained.

II. The Particular Systems of the Planets which have Satellites.

1. *The Syſtem of the Earth.*

Here the Sun is in the center; his Axis inclined 7°, and turns round that Axis in 25 Days, X 14 [illegible] Hours, and 8 Minutes, according to the calculation of M. De la Lande.

The Sun is ſurrounded with a ſmall ring, which repreſents the Plane of the Ecliptic, and a circle on his circumference, perpendicular to his Axis, repreſenting the Solar Equator. Theſe Rings, which interſect each other in two places under an angle of 7°, denote thereby the Nodes of the Sun, ſo that it is eaſily ſeen when the Earth is in the place of theſe Nodes; and conſequently, when the ſpots of the Sun deſcribe ſtraight lines on his Diſk; whilſt they appear rather like Ellipſes, when the Earth is removed three ſigns from the Node. But though the ſpots of the Sun perform their periodical revolutions within the time above mentioned, eti not till after the expiration of 27 Days and 12 Minutes, that they appear again in the place where they have been ſeen 27 Days before; becauſe the Earth, during this time, is likewiſe advanced in the Ecliptic; and that is generally called the Synodic time of the Solar rotation.

The Earth turns round the Sun, and performs its tropic revolution in 365 days, 5 hours, $48\frac{3}{4}$ minutes. By means of a particular motion of the Plane of its orbit, which does not complete its intire revolution in leſs than 26,000 years, we have alſo repreſented the preceſſion of the Equinoxes, or the apparent motion of the fixed Stars from Weſt to Eaſt. By this contrivance the tropic revolution of the Earth is converted into ſiderial revolution, which is 365 days, 6 x 49 hours, and [illegible] minutes.

The globe repreſenting the Earth is one inch in diameter. The four quarters of the world, as well as the principal kingdoms, are engrav[illegible] on it. Its Axis makes an angle of $23\frac{1}{2}^\circ$, with the perpendicular line, and under that angle it performs a complete rotation in 23 hours, 56 minutes, 4 ſeconds, and 5 thirds. By means of a particular contrary motion, this Axis keeps its parallelism in its orbit. This ſerves to explain, in the eaſieſt manner poſſible, the different ſeaſons of the year, the inequalities of days and nights, as well as the riſing and ſetting of the Sun: it alſo indicates what regions have exactly noon, when we have morning, evening, or midnight. It further exhibits our Earth revolving round its Axis in 24 hours, and round the Sun in the ſpace of a year; theſe revolutions clearly ſhew the cauſe of the viciſſitude of the ſeaſons, and produce that Phænomenon which makes it appear to the inhabitants of the Earth as if it was the Sun that riſes and ſets, and paſſes through the different ſigns of the Zodiac.

The Moon revolves round the Earth in 27 days, 7 hours, 43 minutes, and 5 ſeconds, according to her mean motion; but this laſt is likewiſe converted into eccentric motion, by means of another applied in a contrary direction. The line of Apſides, or the Apogée, paſſes through all the ſigns in 3231 days, 8 hours, and 35 minutes; ſo that the Moon always returns into her Apogée at the end of 27 days, 13 hours, 18 minutes, and 34 ſeconds.

As this Satellite paſſes very cloſe to the edge of the ring which repreſents her oblique orbit, ſhe may always be ſeen very diſtinctly when ſhe is approaching to the Earth, and afterwards when receding from it; her orbit interſecting that of the Earth under an angle of 5°. The Moon riſes alſo, of herſelf, from her Nodes over the orbit of the Earth, and deſcends again under it, following always the obliquity of her orbit, which, according to M. De la Lande, performs likewiſe an entire revolution from Eaſt to Weſt, in the courſe of 6798 days, 4 hours, and 53 minutes. It is therefore very eaſy to obſerve, at all times, the Eclipſes happening in and near the Node.

The ſynodic month, where the Moon enters in conjunction with the Sun, is found of itſelf to be 29 days, 12 hours, 44 minutes, $3\frac{2}{10}$ ſeconds; from which it is eaſy to explain the new and full Moon, the firſt and laſt quarter, the place which the Moon occupies in the Zodiac, and all the other Phænomena.

2. *The Syſtem of Jupiter.*

In this ſyſtem the Sun is in the center; the Earth deſcribes a ſmall circle round it: its diſtance from the Sun is, to that of Jupiter from the Sun, as 10 to 52.

Jupiter turns round the Sun and the Earth in 4330 days, 12 hours, according to its true eccentric motion. Its four Satellites turn round it in the following periodic and ſynodic times, exactly calculated by M. De la Lande:

	Days.	Hours.	Min.	Sec.	Times.
Firſt Satellite	1.	18.	27.	33.	Periodic.
	1.	18.	28.	36.	Synodic.
Second Satellite	3.	13.	13.	42.	Periodic.
	3.	13.	17.	54.	Synodic.
Third Satellite	7.	3.	42.	33.	Periodic.
	7.	3.	59.	36.	Synodic.
Fourth Satellite	16.	16.	32.	8.	Periodic.
	16.	18.	5.	7.	Synodic.

The contrivance and conſtruction of the Wheel-work is ſuch, that all theſe motions perfectly agree, even to a ſecond, with thoſe obſerved in the Heavens.

The Earth is alſo placed in this ſyſtem, to ſhew the inequality of the conjunctions of the Satellites with their principal Planets inequality, which is occaſioned by the annual parallax of the Ecliptic; and which, viewed from the Earth, may be eſteemed at the utmoſt:

For the firſt Satellite,	at	1	hour,	25 min.
For the ſecond do.	at	2		50
For the third do.	at	5		44
For the fourth do.	at	13		24

for if the obſerver was ſuppoſed to be in the Sun, this inequality would not happen.

From this it appears, that if any perſon wiſhed to obſerve, in this Machine, the conjunctions of the Satellites, ſuch as they are ſeen from the Earth, they will be found perfectly coinciding with thoſe which happen in the heavens.

Beſides this, if the primary Planet had not obtained in this ſyſtem its eccentric motion proportioned to the elliptic line of its orbit, it would have been impoſſible to make the following differences obvious, which ſhew how much the ſynodic revolutions ſurpaſs the periodic ones,—the motion of Jupiter not being always uniform.

Theſe differences are,

	Hours.	Min.	Sec.
For the firſt Satellite,	0.	39.	22.
For the ſecond do.	1.	19.	13.
For the third do.	2.	39.	42.
For the fourth do.	6.	12.	59.

And this is the ſpace of time for which the motion of the Satellites of the Machine would have differed from that which is obſerved in the heavens.

From this particular account of all theſe ſyſtems it will appear plainly, that it was not very eaſy to add to the eccentric motion of the primary Planet, the like eccentric motion of the Satellites; and at the ſame time to preſent to the view the effect of the parallax, by making the Earth a part of this ſyſtem, in order to make all the revolutions of the Machine perfectly correſpond with thoſe in the heavens.

The Satellites are placed at their proportionable diſtances from their primary Planet; and the ſemidiameter of Jupiter being taken to be the unity, theſe diſtances are:

For the firſt Satellite	5½.
For the ſecond do.	9.
For the third do.	14.
For the fourth do.	25.

Theſe Satellites have an oblique motion, and the Planes of their orbits are inclined 3° to the orbit of the primary Planet, which of itſelf has an inclination of 1° 19′ towards the Ecliptic. By this contrivance the Nodes of the Satellites preſent themſelves to the eye, ſo that it may be ſeen at all times, if the conjunctions obſerved from the Earth happen in or near the Node; and conſequently, if the Eclipſes cauſed by theſe conjunctions, and the paſſages of the Satellites through the ſhadow of Jupiter be of long or ſhort duration. One may alſo perceive if the fourth Satellite of Jupiter will be eclipſed or not; for when it is once at the diſtance of 55°. from the Node, its Eclipſe is no more poſſible. And, laſtly, the time may alſo be known when each Satellite paſſes before the body of Jupiter, ſuch as that paſſage is obſerved from the Earth, as well as the poſition of the Satellites againſt each other, and how they preſent themſelves at all times when they are obſerved by a teleſcope; ſo that in looking for them in the heavens it is eaſily found, by the help of this Machine, which Satellite is the luminous point that is ſeen either on the right or on the left of Jupiter.

3. *The Syſtem of Saturn.*

This ſyſtem is as perfect as that of Jupiter. The Sun is in its center, and the diſtance from the Earth to the Sun is, to that of Saturn from the Sun, as 10 to 95. Saturn performs his elliptic revolution round the Sun in 10,747 days, 3 hours, 23 minutes; its orbit has an inclination of $2\frac{1}{2}$° to that of the Earth, and the periodic and ſynodic revolutions of its five Satellites round the primary Planet, is performed under an angle of 30°.

The revolutions of theſe Satellites, according to M. Proa, whoſe determinations are conſidered as the moſt accurate, and as ſuch adopted by M. De la Lande, are as follows:

	Days.	Hours.	Min.	Sec.	
Firſt Satellite	1.	21.	18.	$26\frac{1}{2}$.	Periodic.
	1.	21.	18.	$55\frac{1}{10}$.	Synodic.
Second do.	2.	17.	44.	$51\frac{1}{2}$.	Periodic.
	2.	17.	45.	$51\frac{9}{10}$.	Synodic.
Third do.	4.	12.	15.	$11\frac{1}{10}$.	Periodic.
	4.	12.	27.	$53\frac{1}{2}$.	Synodic.
Fourth do.	15.	22.	41.	23.	Periodic.
	15.	23.	4.	$12\frac{9}{10}$.	Synodic.
Fifth do.	79.	7.	49.	$10\frac{6}{10}$.	Periodic.
	79.	21.	51.	$85\frac{7}{10}$.	Synodic.

In this ſyſtem, as well as in the Solar ſyſtem where the ſcale is greater, the ring of Saturn has not only its proper obliquity, that is to ſay, an inclination of 30° towards the orbit of Saturn, but alſo its proportionable ſize. The diſtances of the Satellites from the primary Planet are all in due proportions, except the fifth, the diſtance of which would have been too great for the Machine: for if the ſemi-diameter of Saturn is taken as the unity, the inſide edge of the ring is $1\frac{1}{2}$, the outſide 2, the diſtance of the firſt Satellite $4\frac{4}{5}$, that of the ſecond $6\frac{1}{2}$, that of the third $8\frac{3}{4}$, that of the fourth $20\frac{1}{4}$, and that of the fifth ſhould have been 59, but, for want of room, we have been obliged to bring it as near to the fourth as poſſible; and as the four former Satellites turn in the ſame plane with the ring of Saturn, they have all one common Node, which is in the 19° of Virgo.

In obſerving, therefore, the motion of the Satellites, it may always be ſeen when they enter into the ſhadow of Saturn, when they paſs before the body of that Planet, the obſerver being ſuppoſed to be upon our Earth, or what would be the difference cauſed by the parallax of the orbit of the Earth, in regard to the time of their conjunctions with Saturn, if the Earth was not in that ſyſtem.

III. THE CELESTIAL SPHERE; or the SOLAR SYSTEM, as viewed from the EARTH.

This ſyſtem conſiſts of a globe of one foot diameter, made of copper, and painted in blue, on which the fixed ſtars and conſtellations are exactly delineated. It is ſuſpended upon a pillar of the Tuſcan order, ſo as to turn freely on its Axis, within a divided horizon and a graduated meridian. The former may be ſet to any given latitude, and the latter is fixed on the top of the pillar. The globe is encompaſſed by a ſeparate circle, about 1 inch broad, repreſenting the Ecliptic, and the twelve ſigns of the Zodiac; ſo that the globe, with its fixed ſtars, may not only turn freely within the Ecliptic, but may be changed in its poſition, by which means the preceſſion of the Equinoxes may be obſerved.

In the inſide of the globe are about one hundred wheels, which give motion to ſome ſockets that project out of each pole, and to which the Planets, &c. are connected, one above the other, by wires bent to a certain curve. Theſe Planets are even with the Ecliptic, and exhibit on that circle their apparent, direct, and retrograde motions;

tions, and ſometimes they are ſtationary, ſo as perfectly to agree with the apparent places of the real Planets, as ſeen from the Earth; and conſequently their riſing, ſouthing, and ſetting, may be aſcertained to the greateſt exactneſs.

In order to convey a more diſtinct idea of the different parts of this Machine, as alſo of its Mechaniſm and effect, we will give a more particular deſcription thereof.

I.

This Celeſtial Sphere, with its 1500 fixed ſtars and the Milky Way, turns in 23 h. 56′, 4″, 5‴, round its Axis, by a motion from Eaſt to Weſt, according to the diurnal rotation of the Earth, which is performed in the ſame time. By this the poſition, as well as the riſing and ſetting of every fixed ſtar, are determined for every hour of the day and of the night; ſo that this Machine offers a very eaſy and commodious method to obtain a knowledge of the fixed ſtars and of the conſtellations; for, after having ſet it to the meridian, it is ſufficient to figure to oneſelf a ſtrait line, drawn from the centre of the globe to the heavens, in order to find immediately, by the likeneſs of this ſphere with the heavens, the ſame ſtar, or the ſame conſtellation, which riſes on the artificial globe, or which has attained its higheſt meridional altitude. It alſo indicates the apparent motion of the fixed ſtars, by which they advance every day 3′ 55″ 54‴; ſo that after the expiration of ſix months there appear other ſtars on the horizon; and laſtly, it ſhews the ſtars changing every day the time of their riſing and ſetting, till at laſt, after a year's end, they always recover their firſt poſition.

II.

The Sun has the ſame figure as he is commonly repreſented; that is to ſay, from his centre are iſſuing golden beams in all directions, which are to the following uſe. It is well known, that on account of the Crepuſcule (twilight), the night does not begin until the Sun has ſunk 15 or 18 degrees below the horizon; we have therefore conſtructed theſe beams of the length of 15° of a vertical circle, reckoning from the centre of the Sun. By this contrivance it becomes eaſy to determine the beginning and the duration of the twilight, as well as the time during which the Planets, and the fixed ſtars, are concealed by the Sun-beams. For as the Sun moves every day, with all the fixed ſtars, from Eaſt to Weſt, and as by means of another motion, particular to himſelf, he makes a revolution from Weſt to Eaſt in 365 days, 5 hours, 49 min. he paſſes every year before all the Planets and fixed ſtars which are in his way, and covers them by his beams, ſo that thoſe Planets and Stars which riſe and ſet with the Sun cannot be perceived by us. It is therefore always eaſily ſeen on this ſphere, when a ſtar approaches the Sun-beams, when it begins to hide itſelf in the evening-twilight, and when after a ſhort time it appears again on the horizon, before the morning-twilight.

Beſides this, we ſee not only when the center of the Sun riſes over the horizon, or deſcends under it, in the various ſeaſons, but alſo that, according to the different ſigns wherein he finds himſelf, his beams employ more or leſs time to hide themſelves below the horizon, or to appear again before his riſe; whereby they denote the true beginning of the day, and of the night. All theſe Phænomena of the apparent motion are repreſented here. Every 24 hours the Sun is ſeen to come back again under the Meridian, not retarding but a very few minutes, which is called the Equation of time. The reaſon of this difference is as follows: the Sun makes every day a whole revolution, with all the fixed ſtars, in 23 hours, 56′, 4″, 5‴, becauſe his apparent motion is occaſioned by the rotation of the Earth, which is accompliſhed in that time. Now if the Sun had no proper motion, he would always ſeem to come again under the Meridian in the time mentioned above; that is to ſay, in leſs than 24 hours: but as he has alſo every day a retrograde motion from Weſt to Eaſt, by which he deſcribes about one degree in the Ecliptic, it happens by that, that if his proper annual motion is ſuppoſed equal at all times, it is retarded exactly for 3′ 55″ 4‴ by this motion; and, conſequently, he does not require, as the fixed ſtars, only 23 hours, 56′ 4″ 5‴ to come back under the Meridian, but exactly 24 hours.

As the Earth turns round the Sun, not in a circular, but in an elliptic orbit; it is not poſſible that the apparent motion of the Sun, which is produced by it, can be the ſame at all times: it muſt be the ſloweſt in that place of its orbit which is the moſt remote from its center, and which happens in the beginning of the month of July. And whereas this proper motion of the Sun, or rather of the Earth, is ſometimes ſlower and ſometimes quicker, the little quantity of time which the Sun loſes every day, and which changes the day of the ſtars into a natural day, muſt be ſometimes greater and ſometimes ſmaller, ſo that he does not always require exactly 24 hours to come back again under the Meridian.

This elliptic motion of the Sun has been alſo imitated in the Mechaniſm of this ſphere; and conſequently the Sun offers, in this Machine, the ſame Phænomena; and performs his apparent diurnal motion, from Eaſt to Weſt, ſometimes faſter than at others, on account of its eccentricity, as may be ſeen in the Aſtronomical tables, in which the difference of the true and mean time is calculated for every day. This unequal motion is likewiſe the reaſon why the Sun requires 8 days leſs to paſs through the Southern ſigns than through the Northern ones.

Another conſequence of this proper annual motion of the Sun from Eaſt to Weſt (the center of which is the pole of the Ecliptic, diſtant 23° 30′ from the pole of the world, round which turns the whole ſphere with the fixed ſtars, and conſequently alſo the pole of the Ecliptic) is this, that the Sun riſes more over the horizon in the Northern ſigns than in the Southern ones; that he riſes in a ſpiral line from the Tropic of Capricorn to that of Cancer, where he begins his return towards the Equator: in the firſt Solſtice he cauſes the ſhorteſt days, which increaſe by degrees till he arrives in the other, where the days are the longeſt.

III.

The Moon has—1). In the interior part of the ſphere, her periodic complete revolution, which is performed in 27 days, 7 hours, 43 min. 5 ſec. ſo that after a thouſand years ſhe does not find herſelf neither advanced nor retarded; which is the caſe in other Machines of this kind, the Inventors of which were not able to repreſent her revolutions to the exactneſs of a minute.—2). Her mean motion is converted into true motion, by means of a ſmall eccentric diſk, which is applied to the wheel of her mean revolution, and which performs its revolution in a contrary direction in 27 days, 13 hours, 18 min. and 34 ſec. that is to ſay, in the time of an Anomaliſtical month; its diameter is 6 degrees, ſo that her motion is ſlower in the Aphelion, and quicker in the Perihelion, and that the Apogée completes its revolution from Eaſt to Weſt in 3231 days, 8 hours, 35 minutes. If this eccentric motion was not repreſented in this ſphere, the Moon would often be found diſtant 5 or 6 degrees of the Ecliptic from its true poſition, and conſequently the full, as well as the new Moon, would ſometimes happen on the Machine either ten hours too ſoon or too late; and would but ſeldom agree with the heavens. Thus the motion of the Moon, on this Celeſtial ſphere, correſponds ſo exactly with that obſerved in the heavens, that all the other inequalities to which this Satellite is expoſed from various cauſes, never produce even ſo much as one degree difference.

As the courſe of the Moon is here repreſented on a ſphere, ſubject to the diurnal apparent motion of the ſtarry heavens, it will be eaſily perceived, that with the aſſiſtance of this Machine one may obſerve the riſing and ſetting of this Satellite, with its different changes, ariſing from the time of her diſtance from the Sun, and from the place which ſhe occupies in the Zodiac; the unequal motion with which ſhe paſſes through the ſigns of the Ecliptic, and which correſpond with that in the heavens; the apparent and unequal ſpiral progreſſion ſhe deſcribes; that is to ſay, her different meridian elevation over the horizon, which changes according to the place ſhe occupies in the Zodiac; her conjunctions and oppoſitions with the Sun, or the new and full Moons; and laſtly, the fixed Stars and Planets with which ſhe enters every month in conjunction during her paſſage through the Zodiac.

We ſhould have likewiſe repreſented the Moon's orbit, and ſhown how ſhe declines 5° from the courſe of the Sun, at the approach of the ſolſtitial points, ſometimes to the North, and ſometimes to the South, if we had not been afraid to deviate from the principal object of this Machine, which is ſimplicity and ſolidity of its mechaniſm. If we had only had to imitate the motion of the Sun and of the Earth, without conſidering that of the other Planets, it could have been done as eaſily, as to repreſent mechanically the other ſmall inequalities of the Moon, excepting however ſome of them, which it is impoſſible to combine with the revolutions of that Satellite. Inſtead therefore of her orbit, we have repreſented the motion of the Nodes of the Moon: theſe two points, (in which her orbit interſects the Ecliptic under an angle of 5°; that is to ſay, in which the Moon, during her periodic revolution, goes twice through the orbit of the Sun, or of the Earth,) have been made moveable. According to the aſtronomical obſervations and calculations, they make an entire revolution from Eaſt to Weſt; that is to ſay, in a contrary direction, in 6798 days, 5 hours. At the end of their rods there are two diſks, with the ſigns ☊ ☋, the firſt of which denote the aſcending, and the other the deſcending node; ſo that when the Earth paſſes before the firſt of theſe ſigns, it may be eaſily ſeen that ſhe is in the Ecliptic, and that ſhe begins to decline from it, in coming a little nearer to the North. When the Moon is removed 90° from her Node, it is then known that ſhe is in her greateſt ſouthern or northern latitude, which is 5°, and that ſhe is returning in the Ecliptic. As the utmoſt diſtances of the Nodes, in which any eclipſe may happen, are known, a ſmall index, which extends on both ſides of the Ecliptic as far as to 15°, has been added to each ſign of the node; that, when new or full Moons happen within this index, it may be ſoon determined whether any eclipſe of the Sun or the Moon, will take place. To judge afterwards of its magnitude, it will be neceſſary to obſerve whether the conjunctions or oppoſitions of the Sun and of the Moon take place very near or in the Node: and to determine whether they will be viſible or not, it is ſufficient to obſerve whether they happen over our horizon, or under it.

The Nodes of the other Planets are denoted on the Zodiac by ſmall diſks, by means of which it may be perceived, when the Moon covers a Planet, and whether that is viſible or not: that is to ſay, whether ſhe enters in conjunction at night with the Planet, over the Horizon, at the place of the Planet's Node. Theſe Nodes of the Planets have however no proper motion on this Machine, becauſe the time of their revolution is not only very uncertain but alſo very ſlow. However in following the calculations of M. Cassini theſe Nodes may be ſet back every hundred years from Eaſt to Weſt, in the manner following, viz.

The Node of Mercury	1°	24′
That of Venus	0	56′
That of Mars	0	56′
That of Jupiter	0	40′
That of Saturn	1°	35′

except new diſcoveries ſhould be made in that part of Aſtronomy, which might cauſe any alteration: but whether theſe Nodes are ſet back or not, the revolutions of the Planets, even after a great many years, will not fail to be very exact.

IV.

Mercury and Venus, whoſe orbits are ſurrounded by that of the Earth, appear always to be attending the Sun, to an obſerver, who, placed on our globe, makes himſelf an annual revolution round this center of our Planetary ſyſtem. Theſe two Planets continue their courſe from Weſt to Eaſt, till they arrive at a certain diſtance from the Sun; after the ſetting of which they are ſeen yet for ſome time over the horizon; but they very ſoon return, and approach the Sun in the oppoſite direction; and advance by degrees towards the Weſt to a certain diſtance, where they appear before ſun-riſing; and thence are called morning-ſtars. The following is the reſult of the obſervations made on this ſubject.—Mercury performs its revolution from Weſt to Eaſt in about 93 days; it then becomes ſtationary during half a day, and afterwards returns, on the ſame courſe, by a motion from Eaſt to Weſt, in only 22 days. Its greateſt diſtance from the Sun is at from 18 to 28°, but never more. From ſimilar obſervations we know, that Venus performs her revolution from Eaſt to Weſt, in about 542 days; that it is then ſtationary during one day, and returning afterwards, performs the ſame courſe back in 42 days; and is never above 47° diſtant from the Sun.

In that determination of time, Mercury, above all, on account of its greater eccentricity, ſhows a very great inequality. The interval between one conjunction of this Planet with the Sun, until its next conjunction being often 12 days longer than uſual. According to the calculations of M. DE LA LANDE, referring to its mean motion, ſuch an interval of a conjunction may be ſuperior to another as follows, viz. for Mercury 115 days, 21 hours, 3′ 22″; and for Venus 583 days, 22 hours, 7′ 6″.

In order to give all theſe motions, their different directions, poſitions and changes, it was neceſſary to have recourſe to the ſource of theſe Phænomena, and to make ſome parts of the Copernic ſyſtem, relative to this object, the baſe of all theſe apparent changes; we therefore made uſe of the wheel which produced the eccentric motion of the Earth, to repreſent likewiſe the mean revolutions of Mercury and Venus, ſuch as they have been already deſcribed in the Copernic ſyſtem; and having given to all theſe revolutions their proportionate eccentricity, we placed Mercury at 4, and Venus at 7 of the 10 parts which we ſnppoſed between the center of the Sun and the Earth: we then ſuſpended the rod of every Planet within the ſlit of an arm, proportioned to the thickneſs of the rod, and deſcending in a ſtraight line as long as the diameter of the orbit of the Planets required it.

Theſe arms, connected to two ſockets projecting out of the upper part of the globe, give unto the two Planets Mercury and Venus, which are faſtened to the end of the ſteel rods abovementioned, their motion, as it is obſerved from the Earth.

V.

The three ſuperior Planets, Mars, Jupiter, and Saturn, differ in their motions from the two inferior ones, in that, that they deſcribe their orbits without that of the Earth. Obſerved from the Earth, their motion appears quite different; for though Mars performs its mean revolution in 686 days, 22 hours and 21 min. this Planet is however ſeen advancing nearly 705 days in the Zodiac, remaining two days ſtationary, and afterwards retrograding 75 days.—It is likewiſe found retrograding 10 or 12° whenever it is in oppoſition with the Sun; and its retrograde motion is much ſlower than the direct one; for when it is in conjunction with the Sun, it advances 47′ in one day, and in retrograding, it only makes 24′ in the ſame ſpace of time.

Its conjunctions with the Sun always take place at the end of 779 days, 22 hours, 28′ and 26″ of mean motion; but this time is often much prolonged or ſhortened on account of the eccentricity of Mars and the Sun.

The variations in the motions of Jupiter and Saturn which may be obſerved from the Earth, in regard to their ſynodic revolutions are as follows: the interval between one conjunction with the Sun to the other, is

For Jupiter	398 days	21 hours	15′	44″
For Saturn	378	2	8′	7″

In this time Jupiter advances during 284 days, and Saturn during 244 days; at the end of which they remain ſtationary, the firſt 4 days, and the ſecond 8 days: and afterwards the firſt Planet appears retrograding during 119 days, and the ſecond during 136 days; ſo that Jupiter goes back about 10 in the Zodiac, and Saturn about 7°; but both are ſlower in their retrograde motion than they are in their direct one.

When all theſe Phænomena, which reſult from the motion of the Earth, are properly conſidered, it would ſeem almoſt impoſſible to imitate in a Machine all theſe revolutions, which are ſometimes much longer, and ſometimes much ſhorter, on account of their eccentric motion; and which even may take place in different parts of the Zodiac; for Mercury does not reſume the ſame poſition with regard to the Sun till after the expiration of 13 years and 3 days, Venus after 8 years and 2 days, Mars after 15 years and 19 days, Jupiter after 83 years and 1 day, and Saturn after 59 years and 2 days; or rather, to ſpeak properly thoſe Planets never return exactly to the ſame point.

But notwithſtanding theſe difficulties all theſe motions are imitated in this Machine, and agree for more than a thouſand years with thoſe in the heavens: for even if the motion of the Planets is accelerated or retarded by their mutual attraction, that difference will never be ſo much as to be perceptible in a Machine ſo ſmall, in compariſon with the immenſe ſpace of the Heavens, and the magnitude of the prodigious bodies there floating.

All theſe ſeeming unequal motions have been effected in the interior part of this ſphere, by a contrivance and a mechaniſm founded on the Copernic ſyſtem. In conſequence, we have added to the mean and eccentric motion of each of the three ſuperior Planets, and its proportionate diſtance from their center, the motion of the Earth, which is produced by the wheels of their eccentric revolutions.—Thus this Machine exhibits, how theſe Planets run in their ſpiral line, with unequal celerity, and by a motion ſometimes direct and ſometimes retrograding, arrive at different periods to their ſolſtitial points; their meeting each other, riſing and ſetting, paſſing near certain fixed ſtars, and becoming inviſible by hiding themſelves in the beams of the Sun: ſo that this celeſtial ſphere, repreſenting the Univerſe in miniature, ſhews every Phænomena of the celeſtial bodies which may be obſerved either by day or by night; with this only difference, that this moveable celeſtial ſphere is convex, whereas the heavens appear like a concave arch.

This view may be adapted to all latitudes, by placing the horizon to any given degree on the graduated meridian.

IV. THE CHRONOMETER.

This part of the Machine conſiſts of three enamelled dials, one above another, and is put in motion by a Clock.—The uppermoſt dial, being the dial of the Clock, ſhews the hours and minutes; and by advancing the hand that points out the minutes in this dial, not only the Chronometer, but all the other parts of this Aſtronomical Machine are put in motion: the ſecond, or middle dial, has four indexes, one of which alſo ſhews the hours of the day, and makes its revolution every 24 hours; the ſecond ſhews the day of the week; the third ſhews the day of the month: this laſt has five points, under each of which is found the name of ſome month; and that under which the name of the current month is found, ſhews the day of that month. And by this contrivance the exact day of every month is found during the whole year, whether the month has 30 or 31 days. It is only on the laſt of February that this index muſt be advanced 7 days in every common year, and 6 days every Biſſextile or Leap year. The fourth index ſhews the current month. Two indexes on the lowermoſt dial ſhew the years we live in; one of them revolves once in 100 years, and the other in 8000. This laſt points out the two firſt figures, and the former the two laſt, of the chriſtian æra, and the years paſſed ſince the creation of the world.

This Chronometer regulates all the different parts of the whole Aſtronomical Machine. If therefore it ſhould happen, that the Clock ſhould be forgotten to be wound up, not only all the ſyſtems would ſtop in their motion, but alſo all the indexes in the Chronometer, and which would point out in what year, what month, what day, what hour, and what minute the whole Machine was ſtopt.

The hand which marks the hour, conſiſts of two indexes, one over another, and faſtened together by a ſcrew. The uppermoſt is connected with the Aſtronomical ſyſtems,and the other with the Clock only. Thus, if by undoing the ſcrew the ſuperior hand is looſened, and ſeparated from the inferior, the hand which denotes the day may be turned, until all the other indexes of the Chronometer, which mark the time, are exactly upon the preſent day, hour, and minute; and faſtening again the ſuperior hand as before to the inferior one, and ſetting the hand which denotes the minute to the preſent minute,all the different ſyſtems will agree again with the then preſent appearance of the heavens.

By means of the ſame ſcrew and a handle, ſome of theſe ſyſtems may be either ſtopt, advanced, or ſet back for 10, 50, or 100 years, in order to make obſervations upon them, and be ſet again unto their primitive poſitions without either interrupting the motion of the Clock, or putting any thing in the Machine out of order. And though whole days, or months, ſhould be taken up in making ſuch obſervations, the revolutions of the Planets would not vary for a ſecond. It is ſufficient to looſen the hand as mentioned above, and turning that which denotes the days until all the others are brought again to the year, the month, the day, and the hour then preſent, and having again faſtened that hand, by means of the ſcrew, to the inferior one, and ſet theſe joint hands to the exact minute, all the ſyſtems will perfectly agree again with thoſe in the heavens.

SECTION II.

Of the Mechaniſm.

The Clock, which puts the whole in motion, as well as all the other parts of the Aſtronomical ſyſtems, are very accurately made of ſteel and braſs. It has a pendulum, which beats ſeconds, and is put in motion by a weight of 12 pounds, and muſt be wound up every eight days.

As to the ſolidity of this Machine, and the friction to which its various parts are ſubject, there is not the leaſt apprehenſion to be entertained: ſince the ſlow motion of the wheels has been effected by ſo ſmall a force that it meets but little reſiſtance. This may be concluded from the ſmall weight by which the Clock, and by its means, the whole Machine, is put in motion. The weight, it is true, is 12 pounds; but as the Clock is wound up but every 8 days, the proportion thereof, which applies upon the wheel that ſhews the hours, and with which all the other parts of the Machine are connected, is ſcarcely 1½ pound.

The reaſon why ſuch a ſmall force is ſufficient for the motion of ſo many works, is the horizontal arrangement and ſituation of all the parts of the Machine; as no weight is to be raiſed, and all the wheels turn round their centre.

SECTION III.

Of the Exterior Figure.

The outward appearance of this Machine is repreſented in the plate here annexed:

Fig. 1, 2, 3, and 4, repreſent the elevation of this Machine.
Fig. 5, the plan of the ſame.
Fig. 1. The Chronometer.
Fig. 2. Is a glaſs caſe, with a globular top, that contains the Copernic ſyſtem without Satellites.
Fig. 3. Within this caſe are the ſyſtems of the Earth, Jupiter, and Saturn, with their Moons.

Fig. 4. Is the Celeſtial globe upon its pillar, detached from the Machine, as it would hide ſome part of the Chronometer: its proper place is marked with the letter *a* on the plan, Fig. 5.

All the outward parts are made of hard wood, and executed with the greateſt care and perfection. The ornaments are chaſed and double gilt. The ſyſtems are ſurrounded and covered with glaſs; ſo that all the motions may be obſerved without taking off the covers.

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The Chronometer,
and
Planetary Systems.

Fig. 1.

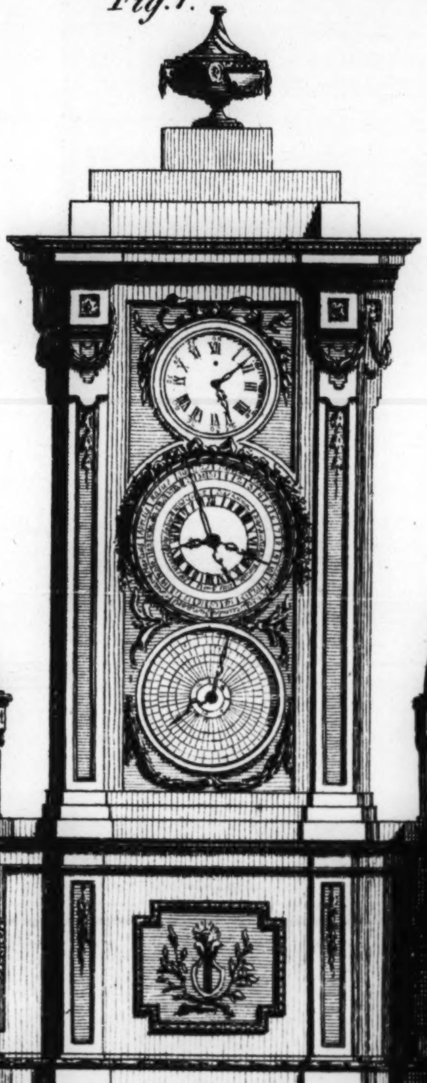


Fig. 4.

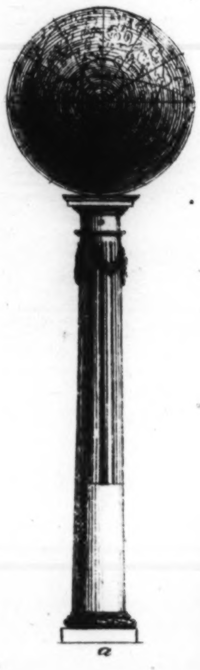


Fig. 3.

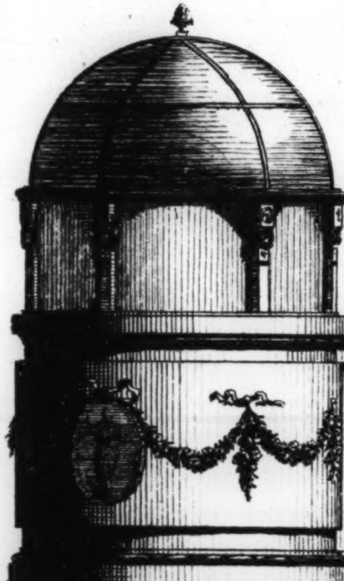
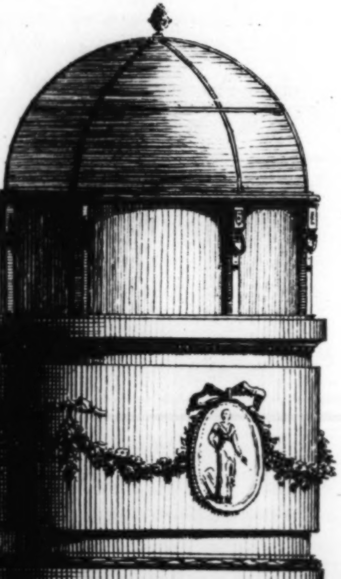
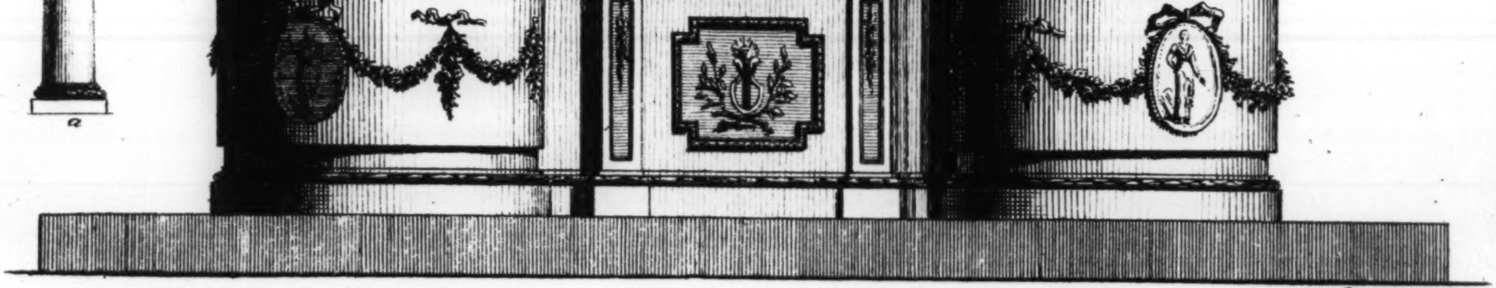


Fig. 2.





Balleis sculp.

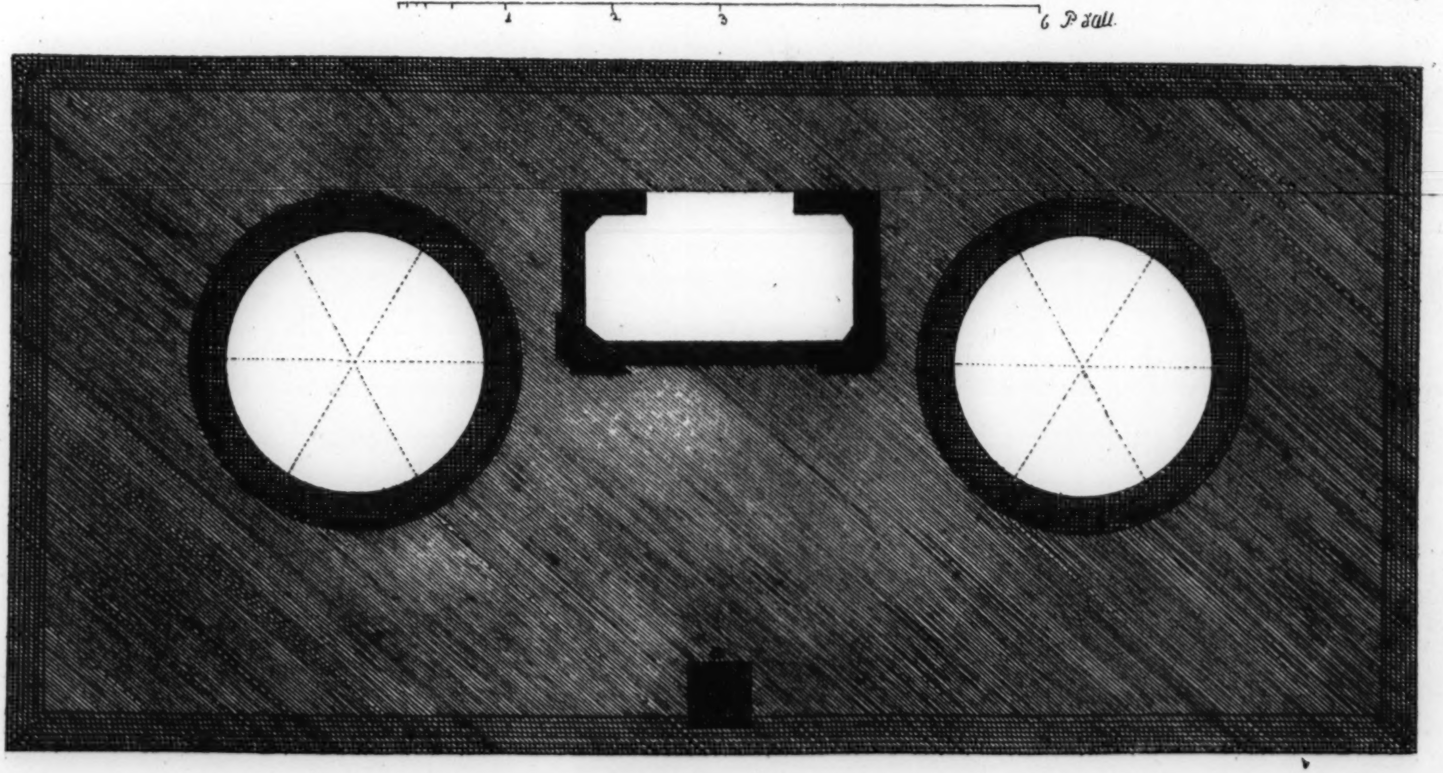


Fig. 5.